Chapter 2
Reconnaissance And Fixes

2.1 GENERAL

JTWC utilizes numerous reconnaissance platforms and observational data sets to locate and analyze tropical cyclones. Satellite and radar have been the primary platforms for "fixing" (location and intensity) tropical cyclones. Conventional land and ship weather observations complement the primary data set and, although sparse in areal coverage, remain the "ground truth" for remotely- sensed data.

2.2 RECONNAISSANCE AVAILABILITY

2.2.1 SATELLITE

Near real-time analysis of visible, infrared and microwave satellite imagery by Air Force and Navy units provides JTWC with tropical cyclone positions and intensity estimates.

2.2.2 RADAR

This data provides location and speed of movement data for tropical cyclones in the proximity (usually within 175 nm (325 km) of radar sites located in Kwajalein, Guam, Japan, South Korea, China, Taiwan, Philippines, Hong Kong, Thailand and Australia. Doppler radars also provide data on cyclone intensity and structure through radial wind measurements in the vertical and horizontal planes.

2.2.3 SYNOPTIC

Analysis of conventional surface and gradient-level synoptic data provides JTWC with additional information on tropical cyclone position and intensity. This data is an important supplement to remotely-sensed platform fixes and are critical to the forecast process in situations where satellite, and radar fixes are not available or are considered unrepresentative.

2.3 SATELLITE RECONNAISSANCE SUMMARY

Per USCINCPACINST 3140.1W, the Commander, Pacific Air Forces (PACAF) is responsible for providing U.S. Pacific Command (USPACOM) tropical cyclone reconnaissance support. Through PACAFINST 15-102, Detachment 1, PACAF Air Operations Squadron (Det 1, PACAF AOS) acts as the Pacific Tropical Cyclone

Satellite Reconnaissance Network controller, tasking and monitoring all satellite reconnaissance efforts. Det 1, PACAF AOS Satellite Operations (SATOPS) is collocated with JTWC at Pearl Harbor, Hawaii. The network sites are listed in Table 2-1.

TABLE 2-1 USPACOM SATELLITE RECONNAISSANCE NETWORK SITES		
UNIT		ICAO
15 OSS/OSW	Hickam AFB, Hawaii	PHIK
18 OSS/OSW	Kadena AB, Japan	RODN
36 OSS/OSW	Andersen AFB, Guam	PGUA
Detachment 1, PACAF AOS	Pearl Harbor, HI	PGTW
607WS	Yongsan AIN, Republic of Korea	RKSZ
AFWA/XOGM	Offutt AFB, NE	KGWC
NAVCENTMETOCDET	Diego Garcia	FJDG

Direct readout network sites provide coverage of the North West Pacific, South China Sea, and south central Indian Ocean using DMSP and NOAA TIROS polar orbiting satellites. PACAFINST 15-102 requires each direct readout site to perform a minimum of two fixes per tropical cyclone per day if a tropical cyclone is within a site's coverage. Network direct readout site coverage is augmented by other sources of satellite-based reconnaissance. AFWA provides AOR-wide coverage to JTWC using recorded Real-time Data Smooth (RDS) DMSP and Global Area Coverage (GAC) NOAA AVHRR imagery. This imagery is recorded and stored on the satellites for later relay to a command readout site, which in turn passes the data to AFWA. Civilian contract weather support for the Army at Kwajalein Atoll provides additional satellite-based tropical cyclone reconnaissance in the Marshall Islands and east of the International Dateline as the opportunity arises. The NOAA/NESDIS Satellite Applications Branch at Camp Springs, Maryland (ICAO identifier KWBC) also provides six-hourly tropical cyclone position and intensity estimates in the JTWC AOR using METEOSAT and GMS geostationary platforms.

Network direct readout sites provide tropical cyclone positions and intensity estimates once JTWC issues either a TCFA or a warning. An example of the Dvorak code is shown in Figure 2-1. Each satellite-derived tropical cyclone position is assigned a Position Code Number (PCN) (Arnold and Olsen, 1974), which is a statistical estimate of fix position accuracy. The PCN is determined by: 1) the availability of visible landmarks in the image that can be used as references for precise gridding, and 2) the degree of organization of the tropical cyclone's cloud system (Table 2-2).

Once a tropical cyclone reaches an intensity of 55 kt, AFWA and Det 1, PACAF AOS SATOPS analyze the 35-kt wind distribution surrounding the tropical cyclone based on microwave satellite imagery. SATOPS provides three-hourly positions and six-hourly intensity estimates for all tropical cyclones in TCFA or warning status. Current intensity estimates are made using the Dvorak technique for both visible and enhanced infrared imagery. The standard relationship between tropical cyclone "T-number", maximum sustained surface wind speed, and minimum sea-level pressure (Atkinson and Holliday, 1977) for the Pacific is shown in Table 2-3. Subtropical cyclone intensity estimates are made using the Hebert and Poteat (1975) technique. Intensity estimates of tropical cyclones undergoing extratropical transition are made using the Miller and Lander (1997) technique.

Det 1, PACAF AOS SATOPS at Pearl Harbor uses hourly full-disk GMS imagery to observe 70% of JTWC's AOR from 80E to 180W (Figure 2-2). Animated geostationary imagery is a valuable tool for determining the location, intensity and motion of tropical cyclones. Additionally, animated water vapor channel imagery is useful for observing synoptic features that affect tropical cyclone development and movement.

The primary satellite reconnaissance system used during the 1998 tropical cyclone season was the Air

TABLE 2-2 POSITION CODE NUMBER (PCN)	
PCN	CENTER DETERMINATION/GRIDDING METHOD
1	EYE/GEOGRAPHY
2	EYE/EPHEMERIS
3	WELL DEFINED CIRCULATION CENTER/GEOGRAPHY
4	WELL DEFINED CIRCULATION CENTER/EPHEMERIS
5	POORLY DEFINED CIRCULATION CENTER/GEOGRAPHY
6	POORLY DEFINED CIRCULATION CENTER/EPHEMERIS

TABLE 2-3 ESTIMATED MAXIMUM SUSTAINED WIND SPEED (KT) AS A FUNCTION OF DVORAK CURRENT AND FORECAST INTENSITY NUMBER AND MINIMUM SEA-LEVEL PRESSURE (MSLP)

T-NUMBER	ESTIMATED WIND SPEED-KT(M/SEC)		MSLP(MB)(PACIFIC)
0.0	lt 25	lt (13)	—
0.5	25	(50)	—
1.0	25	(50)	—
1.5	25	(50)	—
2.0	30	(60)	1000
2.5	35	(70)	997
3.0	45	(90)	991
3.5	55	(110)	984
4.0	65	(130)	976
4.5	77	(154)	966
5.0	90	(180)	954
5.5	102	(204)	941
6.0	115	(230)	927
6.5	127	(254)	914
7.0	140	(280)	898

Force Mark IVB. SATOPS on an interim basis, also used the SMQ-11E, Navy Satellite Display System - Enhanced (NSDS-E) to access polar and geostationary data starting in December 1998.

The Air Force Mark IVB satellite system is undergoing a program-wide $6 million Pre-planned Product Improvement to increase its processing speed and networking capability. A client workstation is scheduled to be installed at JTWC in late 1999 and become the primary satellite reconnaissance display and analysis system. The Mark IVB will then display NOAA Advanced Very High Resolution Radiometer (AVHRR), DMSP Operational Linescan System (OLS), Special Sensor Microwave/Imager (SSM/I), Microwave/Sounder (SSM/T1 and SSM/T2), and also geostationary visible, infrared and water vapor channel imagery.

NOAA TIROS AVHRR imagery provides five channels of imagery: visible, near and middle IR, and two in the far IR channels. DMSP OLS provides imagery in two channels: visible/near IR (commonly referred as broadband visible), and far IR.

2.3.1 SATELLITE PLATFORM SUMMARY

Imagery was received from various sensors on three DMSP (F12, F13 and F14) and three NOAA (N12, N14 and N15) satellites during 1998.

2.3.2 STATISTICAL SUMMARY

As directed by Base Realignment and Closure (1995), the satellite operations section relocated from Guam to Hawaii with JTWC in October through December of 1998 and officially became operational on 1 Jan 1999. During 1998, the PACOM Tropical Cyclone Satellite Reconnaissance Network and other agencies provided JTWC with 6,032 fixes: 2,420 NWP, 511 North Indian Ocean, and 3,101 Southern Hemisphere. SATOPS provided 3,221, accounting for nearly 53% of all fixes.

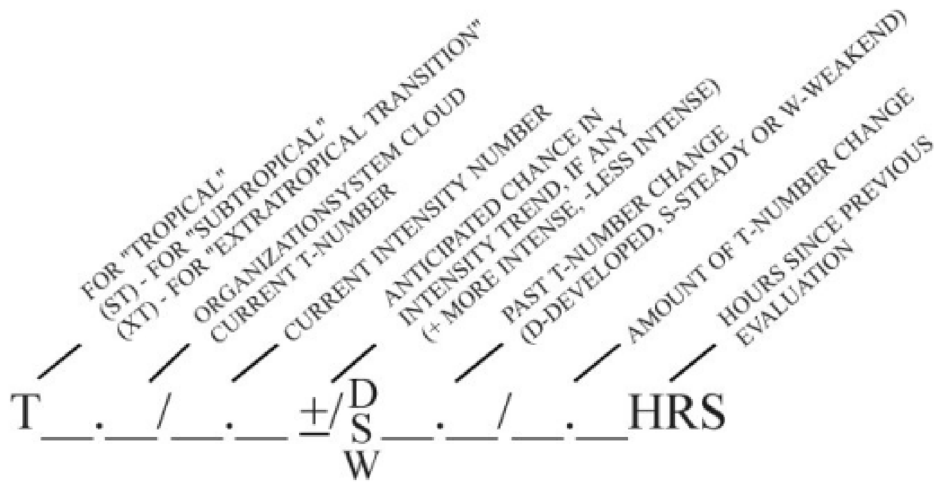

Figure 2-1. Dvorak code for estimating current and forecast intensity from satellite data. In the example, the current T-number is 3.5, but the current intensity is 4.5. The cloud system has weakened by 1.5 "T-numbers" since the evaluation conducted 24 hours earlier.

2.3.3 APPLICATIONS OF NEW TECHNIQUES AND TECHNOLOGY

SATOPS began use of microwave imagery from the Tropical Rainfall Measurement Mission research (TRMM) satellite. This low-earth orbit satellite has a nine-channel passive microwave radiometer similar to the DMSP SSM/I but at half the altitude. While its usable swath width is roughly half as wide as DMSP SSM/I, TRMM's resolution is much better. Additionally, its equatorial orbit (35 degree inclination angle) provides better coverage of JTWC's tropical area of responsibility. The acquisition of DMSP F14 data in the early summer helped increase the area covered by microwave imagery. Additionally, to give the TDO a better statistical value for each satellite derived fix, SATOPS continued to use animated geostationary imagery and multispectral display capability to apply Position Code Numbers (PCN) (Table 2-4) and fix codes to a particular tropical cyclone pattern based on sensor type. The XT technique (Miller and Lander, 1997) continued to be used operationally to better estimate tropical cyclones undergoing extratropical transition.

Table 2-4 POSITION CODE NUMBER (PCN) CRITERIA AND FIX CODES FOR TC LOW-LEVEL CCs FROM SATELLITE (Note 1)

PCN	PCN	Definitions	Sensor /technique type and fix code					
Grid by Geography (note 2)	Grid by Ephemeris (note 2)		IR	Vis	Both	SSM/I only (note 3)	Vis/IR &SSM/I (note 3)	Anmtn (note 4)
1	2	Eye						
(EYE)	(EYE)	CDO type eye, geometric center (regular, round, any diameter) (note 6)	1	2	3	4	S	A
(EYE)	(EYE)	Small eye (irregular/ragged, diameter 30 nm on long axis) (note 6)	5	6	7	8	S	A
3	4	Well defined CC						
(EYE)	(EYE)	Eye(ragged/irregular, diameter &30nm center &1/2 enclosed by wall cloud (note 6)	9	10	11	12	S	A
(EYE)	(EYE)	Tightly curved band/banding type eye (band curves at least 1/2 distance around center, diameter 90 nm)	13	14	15	16	S	A
(LLCC)	(LLCC)	Exposed low-level CC	17	18	19	20	S	A
(CDO)	(CDO)	Small CDO (round with well defined edges, positioned near geometric center, diameter 80 nm)		21	22	23	S	A
(EMB)	(EMB)	Small embedded center (diameter 80 nm)	24		25	26	S	A
(CDO)	(CDO)	Large CDO (with clear indications of shearing, low-level cloud lines, or overshooting tops that bias low-level center position away from the geometric center, diameter 80 nm)		27	28	29	S	A
(CDO)	(CDO)	Any CDO or Embedded Center with low-level CC clearly visible on co-registered SSM/I (note 7)	30	31	32	33	S	

Table 2-4 POSITION CODE NUMBER (PCN) CRITERIA AND FIX CODES FOR TC LOW-LEVEL CCs FROM SATELLITE (Note 1)

5	6	Poorly Defined						
		Large eye (ragged/irregular, 30 nm diameter on long axis, 1/2 enclosed by wall cloud)	34	35	36	37	S	A
		Spiral banding systems (convective curvature) not classifiable as banding eye or tightly curved band	38	39	40	41	S	A
		Large CDO		43	44	45	S	A
		Embedded center positioned with IR	46					A
		Partially exposed low-level centers with the CC less than half exposed	47	48	49	50	S	A
		Cloud minimum wedge/cold comma	51	52	53	54	S	A
		Central cold cover	55	56	57	58	S	A
		Cirrus outflow - upper level outflow provides the only circulation parameters	59	60	61	62	S	A
		Poorly organized low-level center evident only in high resolution animation (Vis/IR or both)						
		All others						
		Monsoon depressions or multiple cloud clusters, positioned using any of the following methods:	Any combination of Vis , IR/EIR					
		Cirle method	68					
		Conservative feature	69					A
		Animation	70					
		Extrapolation	71					

Note 1: Use the following steps to determine the PCN and Fix Code: a. Based on the analysis of the circulation parameters, determine a TC low-level CC position. b. Go to Table 2-2, then to the definitions column. Choose a PCN based on the cloud pattern, discrete measurements, as necessary, and/or technique used to determine the position. c. Move across to the Fix Code columns, and based on the sensor(s) used, select a fix code.

Note 2: Odd PCNs (1, 3, 5) are gridded with geography, the low-level CC being within 10 degrees (600 nm) of the geographic feature used for gridding. Even PCNs (2, 4, 6) are gridded with ephemeris, or the low-level CC is not within 10 degrees (600 nm) of the geographic feature used for gridding.

Note 3: SSM/I only fixes - Use PCN of 5 or 6, and fix code based on Note 1, para a c.

Note 4: Append S to the numerical fix code entry to indicate Special Sensor Microwave Imager (SSM/I) and visible and/or infrared data was used in determining the low-level CC (i.e. 18S). Defense Meteorological Satellite Program (DMSP) fixes only. For the purposes of this fix code, SSM/I (S) and Animation (A) are mutually exclusive.

Note 5: Append A to the numerical fix code entry to indicate animation was used in determining the low-level CC (i.e. 11A). Geostationary fixes only. For the purposes of this fix code, SSM/I (S) and Animation (A) are mutually exclusive.

Note 6: For fix code entries 1-9, encode 01-09.

Note 7: In order to use SSM/I data to position low-level CCs, you must be able to correct the navigation/gridding and interrogate the SSM/I imagery directly for latitude/longitude (DMSP fixes only).

2.3.4 FUTURE OF SATELLITE RECONNAISSANCE

Research is being conducted to develop a method of integrating passive microwave radiometer imagery into the Dvorak position and intensity estimate technique. This technique currently relies exclusively on visible and enhanced infrared. Using microwave imagery – which can see through obscuring layers of cirrostratus cloud decks – will provide early warning of significant changes in tropical cyclone convective structure. Additionally, SATOPS anticipates far more frequent and usable scatterometer data from the NASA QuikSCAT satellite, which is scheduled for launch in mid-1999. This satellite, whose active microwave sensor measures backscatter from the ocean surface to determine both the direction and speed of surface winds, will have a swath width of approximately 1,800 kilometers, over twice that of the European ERS-2 scatterometer. Increased swath width will result in more frequent useable passes as well as the capability to routinely determine 35-knot wind distribution around strong tropical cyclones.

2.4 RADAR RECONNAISSANCE SUMMARY

Of the 27 NWP significant tropical cyclones, 6 passed within range of land-based radar with sufficient precipitation and organization to be fixed. A total of 88 land-based radar fixes were logged at JTWC. As defined by the World Meteorological Organization (WMO), the accuracy of these fixes falls within three categories: good [within 10 km (5 nm)], fair [within 10 - 30 km (5 - 16 nm)], and poor [within 30 - 50 km (16 - 27 nm)]. Of the 88 radar fixes encoded in this manner, 15 were good, 45 were fair, and 28 were poor. The radar network provided timely and accurate fixes which allowed JTWC to better track and forecast tropical cyclone movement. In the Southern Hemisphere, 20 radar reports were logged for tropical cyclones. No radar fixes were received for the North Indian Ocean.

2.5 TROPICAL CYCLONE FIX DATA

Table 2-5a shows the number of fixes per platform for each individual tropical cyclone for the NWP. Totals and percentages are also shown. Similar information is provided for the North Indian Ocean in Table 2-5b, and for the South Pacific and South Indian Ocean in Table 2-5c.

TABLE 2-5a WESTERN NORTH PACIFIC OCEAN FIX SUMMARY FOR 1998

TROPICAL CYCLONE	SATELLITE	SCATTEROMETER	RADAR(P/F/G)	SYNOPTIC	TOTAL
01W	72	1	0	0	73
02W NICHOLE	93	1	15/0/0	0	109
03W	31	0	0	0	31
04W OTTO	85	1	0	2	88
05W PENNY	122	1	0	2	125
06W REX	359	3	0	0	362
07W	35	0	0	0	35
08W STELLA	94	2	0	8	104
09W	19	0	0	0	19
10W TODD	102	1	0	4	107
11W VICKI	143	1	3/6/1	13	167
12W	27	0	0	0	27
13W WALDO	38	0	0	7	45
14W YANNI	98	2	5/4/5	11	125
15W	51	1	0	3	55
16W	51	0	0	3	54
17W	15	0	0	2	17
18W ZEB	205	2	4/2/4	33	248
19W ALEX	27	0	1/6/5	1	39
20W BABS	334	4	0/27/0	14	379
21W CHIP	61	0	0	1	62
22W DAWN	53	0	0	0	53
23W ELVIS	43	1	0	1	45
24W FAITH	134	1	0	1	136
25W GIL	68	1	0	2	71
26W	32	0	0	1	33
27W	43	0	0	0	43
TOTALS	2435	23	88	99	2652
PERCENTAGE OF TOTAL	92	1	3	4	100

TABLE 2-5b NORTH INDIAN OCEAN FIX SUMMARY FOR 1998

TROPICAL CYCLONE	SATELLITE	SCATTEROMETER	RADAR	SYNOPTIC	TOTAL
01B	110	1	0	0	111
02A	9	2	0	0	11
03A	109	3	0	1	113
04A	10	0	0	0	10
05A	24	0	0	1	25
06B	49	0	0	0	49
07B	119	0	0	1	120
08A	84	1	0	0	85
TOTALS	514	7	0	3	524
PERCENTAGE OF TOTAL	98	1	0	1	100

TABLE 2-5c SOUTH PACIFIC AND SOUTH INDIAN OCEAN FIX SUMMARY FOR 1998

TROPICAL CYCLONE	SATELLITE	SCATTEROMETER	RADAR(P/F/G)	SYNOPTIC	TOTAL
01S	79	2	0	0	81
02P LUSI	96	4	0	1	101
03P	38	2	0	2	42
04P MARTIN	42	0	0	0	42
05P	76	3	0	4	83
06P OSEA	56	0	0	0	56
07P PAM	73	0	0	0	73
08S	54	0	1/2/0	2	59
09S SELWYN	125	3	0	0	128
10P RON	120	0	0	0	120
11P SUSAN	121	3	0	0	124
12P KATRINA	492	5	0/0/5	18	520
13P	50	2	0	0	52
14P LES	152	1	1/0/0	1	155
15S TIFFANY	151	1	0/7/4	0	163
16P TUI	21	0	0	0	21
17P URSULA	13	0	0	0	13
18P VELI	31	0	0	0	31
19P WES	49	0	0	1	50
20S ANACELLE	114	2	0	0	116
21S	43	1	0	0	44
22P VICTOR	187	2	0	2	191
23P	58	1	0	1	60
24S	32	1	0	0	33
25P MAY	48	0	0	0	48
26S DONALINE	57	1	0	0	58
27S ELSIE	227	2	0	0	229
28S FIONA	76	2	0	0	78
29P YALI	176	3	0	0	179
30P NATHAN	180	2	0	2	184
31P ZUMAN	180	3	0	0	183
32S	167	2	0	1	170
33S	13	0	0	0	13
34S	79	0	0	0	79
35S	46	2	0	0	48
36P ALAN	46	0	0	0	46
37P BART	20	0	0	0	20
TOTALS	3588	51	20	34	3693
PERCENTAGE OF TOTAL	97	1	1	1	100